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STUDIES ON THE DIGESTIBILITY OF SOME NUT OILS.[1]

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INTRODUCTION.

This paper records the results of a study of the digestibility of almond, black-walnut, Brazil-nut, butternut, English-walnut, hickory-nut, and pecan oils.

Previous papers[2] of this series have reported the digestibility of lard, beef fat, mutton fat (kidney fats), butter; cream, chicken, goose, fish, brisket, and egg-yolk fats; and cocoa butter, olive, cottonseed, peanut, coconut, and sesame oils. The results of the study of the digestibility of these fats indicate that they are well utilized by the human body and may be used in amounts exceeding those of the ordinary diet, without causing any laxative effects. In the experiments all of the fats were separated from the materials in which they naturally occur. Most of them are thus used in the ordinary diet, though with a few (egg fat and fish fat, for example) this is not the case. The present paper has to do with the digestibility of the oils obtained from some of the common nuts considered in comparison with the digestibility of the large number of animal and vegetable fats which are being considered in this series. While these oils can

[1] Prepared under the direction of C. F. Langworthy, Chief, Office of Home Economics.

[2] U. S. Dept. Agr. Buls. 310 (1915), 505 (1917), 507 (1917).

NOTE.—This bulletin is primarily of interest to students and investigators of food problems.

not be purchased in any considerable quantities and are little used in this country as such, very considerable quantities are consumed annually as a constitutent of the nuts in which they occur.

Inasmuch as sufficient quantities of these nut oils could not be procured in the open market, a supply of good grade nuts of the varieties to be studied was procured and the oils were expressed under laboratory conditions with a hydraulic press having a capacity of 35 tons pressure on a 6-inch plunger. All of the oils were "cold pressed" and were of excellent quality, being in such good condition that no refining was necessary. They were allowed to stand some hours in order that any suspended matter might settle and then they were filtered through one thickness of ordinary filter paper. In all instances the oils were of good color, without odor, and possessed a bland flavor; in one or two instances more or less of the characteristic flavor of the nuts from which the oils were derived could be detected. Since they were used within a short time after they were expressed, little information was obtained in regard to the keeping quality of the oils.

The press cake remaining after the oils had been expressed from the nuts was quite palatable though not as "rich" as the nuts, and rather dry if eaten alone. The characteristic flavor of the nuts was retained by it and was in many cases intensified. Since the press cake was derived from a good grade of cleaned nuts it had considerable interest as a possible food material, especially in view of its high protein content. That obtained from several varieties of nuts was accordingly studied in this office from a dietetic standpoint, and various recipes for its use were developed. The value and possible uses of such press cake will be discussed in a later publication.

In the studies of the digestibility of the 16 animal or vegetable fats, reported in previous bulletins, an average of eight tests was made with each fat; in only one case were there less than five experiments. Because of the limited available supply of the oils considered in this paper only three or four tests could be made with the oils studied.

METHODS OF PROCEDURE.

The digestion experiments with the nut oils were conducted by the same methods as those with the animal and vegetable fats already reported, the object being to maintain identical experimental conditions for each fat studied and thus to make the values obtained for the digestibility of the different fats directly comparable with one another.

As in the earlier experiments, a blancmange, or cornstarch pudding, served as the medium for introducing the fat under consideration. The blancmange was prepared by the method outlined in a

previous paper[1] and in amounts sufficient to supply all the subjects for the entire experimental period. In order to mask the presence of the large quantity of fat and to secure a blancmange which would be of uniform color and flavor for all experiments, thus avoiding as far as possible any psychic effects, a caramel solution was added to the blancmange during its preparation.[2]

The accessory foods which the diet contained in addition to the blancmange and which were selected because they supplied a minimum of fat, were wheat biscuit, oranges, and sugar. In case the subjects so desired, they were permitted to take tea or coffee, without milk or cream, with their meals. All constituents of the diet except the tea or coffee were eaten cold.

The feces resulting from the diet under consideration were identified by means of charcoal taken in gelatin capsules with the first meal of the test period and with the first meal following the test period. The feces were collected in weighed glass containers and dried in an electric oven regulated to maintain a temperature of 95° C., pulverized and analyzed. The urine was not collected or analyzed, and no attempt was made to maintain a nitrogen equilibrium, since in this investigation attention was centered on the digestibility of the fats.

The customary three-day or nine-meal test period was judged to be of sufficient duration to permit of satisfactory analytical results and still not so long as to become monotonous. No record of the body weights of the subjects was kept, but the men were expected to submit a report of their physical condition during the interdiet periods as well as during the experimental periods. As they reported being in normal physical condition throughout the investigation their reports will not be referred to in detail.

SUBJECTS.

Men between 20 and 40 years of age, of normal health and appetite, served as subjects for this investigation. With one exception, they were all students and, while they were mainly engaged in mental activities, their exercise was enough to make their energy requirements considerably in excess of those persons with sedentary occupations. They had all had previous experience in such experimental work and fully appreciated the necessity for accuracy in carrying out the directions given, saving uneaten portions of food, collecting

[1] U. S. Dept. Agr. Bul. 310 (1915).

[2] Recently Plaisance and Monsch (Jour. Home Econ., 9 (1917), No. 4, p. 167) have reported that when caramel is prepared by heating sugar at temperatures of 180° C. and 200° C. from 0.02 per cent to 0.09 per cent of furfurol is formed. The authors further state that if the caramel is subsequently cooked in the presence of water the furfurol is removed, which perhaps may explain the absence of any toxic effects resulting from the use of caramel in the preparation of the blancmange.

feces, etc. While there were no prescribed hours for eating, the subjects were informed that regularity was desired and they were requested to follow their normal daily routine as far as possible.

ALMOND OIL.

Commercial almond oil is obtained by subjecting the seeds of *Prunus amygdalus* to hydraulic pressure. Almond oil, of which considerable quantities appear in commerce, is principally used in the preparation of ointments, emulsions, and toilet soaps. It possesses, however, all the essentials characteristic of an edible oil, and hence the question of its value as human food is an interesting one. The literature shows no investigations of the digestibility of almond oil as such.

In a series of digestion experiments conducted to determine the relative digestibility of fruits and nuts Jaffa[1] studied the digestibility of almonds eaten in conjunction with bananas, apples, dates, olives, and oranges combined in different ways. The total fat of the diet was found to be 84 per cent digested. Inasmuch as 83 per cent, or approximately 97 grams of the 117 grams of fat eaten daily, was derived from the almonds, this value should very nearly represent the digestibility of almond oil when eaten as a constituent of almonds.

The almond oil studied in this investigation was prepared by expression from a supply of first quality sweet almond nuts purchased in the open market. The oil which was obtained had no marked flavor or odor and, judged by household tests, was a very satisfactory table oil. It was incorporated in the usual cornstarch blancmange and eaten by the four subjects who assisted in this study. The results of the four experiments are included in the following table:

Data of digestion experiments with almond oil in a simple mixed diet.

Experiment, subject, and diet.	Weight of foods.	Constituents of foods.				
		Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 555, subject H. R. G.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Blancmange containing almond oil	1,463.0	672.0	27.4	170.9	580.0	12.7
Wheat biscuit	306.0	27.6	32.4	4.6	236.5	4.9
Fruit	458.0	398.0	3.7	0.9	53.1	2.3
Sugar	17.0	.....	.....	.....	17.0	.....
Total food consumed	2,244.0	1,097.6	63.5	176.4	886.6	19.9
Feces	77.0	.....	24.6	6.7	40.0	5.7
Amount utilized	.....	.....	38.9	169.7	846.6	14.2
Per cent utilized	.....	.....	61.3	96.2	95.5	71.4

[1] U. S. Dept. Agr., Office Expt. Stas. Bul. 132 (1903).

Data of digestion experiments with almond oil in a simple mixed diet—Contd.

Experiment, subject, and diet.	Weight of foods.	Constituents of foods.				
		Water.	Protein.	Fat.	Carbohydrates.	Ash.
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Experiment No. 556, subject A. J. H.:						
Blancmange containing almond oil	1,671.0	767.5	31.2	195.2	662.6	14.5
Wheat biscuit						
Fruit	324.0	281.6	2.6	0.6	37.6	1.6
Sugar	42.0				42.0	
Total food consumed	2,037.0	1,049.1	33.8	195.8	742.2	16.1
Feces	85.0		27.1	26.9	21.4	9.6
Amount utilized			6.7	168.9	720.8	6.5
Per cent utilized			19.8	86.3	97.1	40.4
Experiment No. 557, subject P. K.:						
Blancmange containing almond oil	2,069.0	950.3	38.7	241.7	820.3	18.0
Wheat biscuit	320.0	28.8	33.9	4.8	247.4	5.1
Fruit	638.0	554.4	5.1	1.3	74.0	3.2
Sugar	67.0				67.0	
Total food consumed	3,094.0	1,533.5	77.7	247.8	1,208.7	26.3
Feces	89.0		28.4	13.7	38.7	8.2
Amount utilized			49.3	234.1	1,170.0	18.1
Per cent utilized			63.4	94.5	96.8	68.8
Experiment No. 558, subject C. J. W.:						
Blancmange containing almond oil	1,945.0	893.3	36.4	227.2	771.2	16.9
Wheat biscuit	287.0	25.8	30.4	4.3	221.9	4.6
Fruit	975.0	847.3	7.8	1.9	113.1	4.9
Sugar	29.0				29.0	
Total food consumed	3,236.0	1,766.4	74.6	233.4	1,135.2	26.4
Feces	102.0		32.8	10.7	50.2	8.3
Amount utilized			41.8	222.7	1,085.0	18.1
Per cent utilized			56.0	95.4	95.6	68.6
Average food consumed per subject per day	884.3	453.9	20.8	71.1	331.1	7.4

Summary of digestion experiments with almond oil in a simple mixed diet.

Experiment No.	Subject.	Protein.	Fat.	Carbohydrates.	Ash.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
555	H. R. G.	61.3	96.2	95.5	71.4
556	A. J. H.	19.8	86.3	97.1	40 4
557	P. K.	63.4	94.5	96. 8	68.8
558	C. J. W.	56.0	95.4	95.6	68.6
	Average	50.1	93.1	96.3	62.3

In the four experiments made with the almond oil an average of 21 grams of protein, 71 grams of fat (of which 70 grams was almond oil), and 331 grams of carbohydrates was eaten per man per day, and of these amounts 50.1 per cent of the protein, 93.1 per cent of the fat, and 96.3 per cent of the carbohydrates was digested. The value, 93.1 per cent obtained for the digestibility of fat, applies to the digestibility of the total fat of the diet and is increased to 97.1 when allowance is made for the undigested residue resulting from the basal ration and occurring in the ether extract of the feces.

The coefficient of digestibility of almond oil as determined by these experiments is, for all practical purposes, identical with the coefficient of digestibility, 97 per cent, reported in an earlier paper[1] of this series for the most widely used animal fats, butter, and lard.

BLACK-WALNUT OIL.

Black-walnut oil, which is obtained from the nuts of *Juglans nigra*, is commercially classified as a drying oil. When free from fatty acid, it is said to be preferred to any other oil for making artists' white paints, since it makes them less liable to crack than if prepared with linseed oil. Black walnuts are rich in oil,[2] 56 per cent being contained in the edible portion, and when subjected to pressure yield a yellow oil possessing the characteristic odor and flavor of the nuts. Although this flavor is esteemed by many, it is somewhat too pronounced to make this oil as generally adaptable for cooking or salad purposes as the others here considered.

A supply of first quality nuts was obtained from a local dealer. The kernels were ground in a common household meat chopper, after which the oil was extracted by hydraulic pressure without heating; approximately a 50 per cent yield resulting.

In all other determinations of the coefficients of digestibility of the many fats included in this series, the basal ration served in conjunction with the blancmange, which contained the fat under consideration, consisted of wheat biscuit, fruit, sugar, and tea or coffee if desired. The basal ration served in the experiments with the black-walnut oil was of a slightly different composition, because, owing to the exhaustion of the available supply of the wheat biscuit, it became necessary to replace them by crackers. However, since the composition of the crackers was quite similar to that of the wheat biscuit, it is not thought that this change in the basal ration has in any way vitiated the values obtained in these experiments for comparison with values obtained for the digestibility of other oils studied.

Four young men of normal health and activity served as subjects for the tests made with the black-walnut oil; the following tables contain the essential data for interpreting the results obtained.

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[1] U. S. Dept. Agr. Bul. 310 (1915).

[2] U. S. Dept. Agr., Office Expt. Stas. Bul. 28 (1906), rev. ed.

Data of digestion experiments with black-walnut oil in a simple mixed diet.

Experiment, subject, and diet.	Weight of foods.	Constituents of foods.				
		Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 565, subject H. R. G.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Blancmange containing black-walnut oil	1,406.0	685.6	27.3	127.1	555.2	10.8
Crackers	288.0	19.9	23.3	38.6	203.9	2.3
Fruit	464.0	403.2	3.7	1.0	53.8	2.3
Sugar	.....	.....	.....	.....	.....	.....
Total food consumed	2,158.0	1,108.7	54.3	166.7	812.9	15.4
Feces	51.0	.....	19.5	6.5	20.2	4.8
Amount utilized	.....	.....	34.8	160.2	792.7	10.6
Per cent utilized	.....	.....	64.1	96.1	97.5	68.8
Experiment No. 566, subject A. J. H.:						
Blancmange containing black-walnut oil	1,800.0	877.7	34.9	162.7	710.8	13.9
Crackers	132.0	9.1	10.7	17.7	93.5	1.0
Fruit	145.0	126.0	1.2	.3	16.8	.7
Sugar	85.0	.....	.....	.....	85.0	.....
Total food consumed	2,162.0	1,012.8	46.8	180.7	906.1	15.6
Feces	70.0	.....	25.5	14.6	22.7	7.2
Amount utilized	.....	.....	21.3	166.1	883.4	8.4
Per cent utilized	.....	.....	45.5	91.9	97.5	53.8
Experiment No. 567, subject P. K.:						
Blancmange containing black-walnut oil	2,115.0	1,031.3	41.0	191.2	835.2	16.3
Crackers	308.0	21.2	24.9	41.3	218.1	2.5
Fruit	788.0	684.8	6.3	1.6	91.4	3.9
Sugar	100.0	.....	.....	.....	100.0	.....
Total food consumed	3,311.0	1,737.3	72.2	234.1	1,244.7	22.7
Feces	47.0	.....	17.4	7.8	17.0	4.8
Amount utilized	.....	.....	54.8	226.3	1,227.7	17.9
Per cent utilized	.....	.....	75.9	96.7	98.6	78.9
Experiment No. 568, subject C. J. W.:						
Blancmange containing black-walnut oil	2,125.0	1,036.1	41.2	192.1	839.2	16.4
Crackers	293.0	20.2	23.7	39.3	207.5	2.3
Fruit	792.0	688.2	6.3	1.6	91.9	4.0
Sugar	74.0	.....	.....	.....	74.0	.....
Total food consumed	3,284.0	1,744.5	71.2	233.0	1,212.6	22.7
Feces	81.0	.....	29.4	12.8	30.8	8.0
Amount utilized	.....	.....	41.8	220.2	1,181.8	14.7
Per cent utilized	.....	.....	58.7	94.5	97.5	64.8
Average food consumed per subject per day	909.6	466.9	20.4	67.9	348.0	6.4

Summary of digestion experiments with black-walnut oil in a simple mixed diet.

Experiment No.	Subject.	Protein.	Fat.	Carbohydrates.	Ash.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
565	H. R. G.	64.1	96.1	97.5	68.8
566	A. J. H.	45.5	91.9	97.5	53.8
567	P. K.	75.9	96.7	98.6	78.9
568	C. J. W.	58.7	94.5	97.5	64.8
	Average	61.1	94.8	97.8	66.6

It will be noted from the above data of the digestion experiments with black-walnut oil that the total fat of the diet was 94.8 per cent digested. On an average 56 grams of black-walnut oil were eaten per man per day. If allowance is made for the ether-extracted material resulting from the nonfatty portion of the diet, the digestibility of

black-walnut oil becomes 97.5 per cent. The protein and carbohydrate portions of the diet were 61.1 per cent and 97.8 per cent digested, respectively, figures comparing favorably with those usually obtained for these constituents in other tests of this series, and indicating that this oil does not decrease the digestibility of other food materials consumed in conjunction with it.

BRAZIL-NUT OIL.

Brazil-nut oil is obtained from the seeds of *Bertholletia excelsa*, which is indigenous to tropical South America, and which occurs there in both the wild and the cultivated state. These nuts are especially rich in oil, which, according to Lewkowitsch,[1] may make up as much as 73 per cent of the dried nuts.

The oil, obtained by cold pressing a quantity of fresh Brazil nuts, was odorless and nearly colorless, and possessed a flavor similar to that of the nuts, though very much less pronounced.

Jaffa[2] studied the digestibility of Brazil nuts when eaten as a part of diets containing such foods as apples, bananas, granose (a wheat preparation), grapes, honey, milk, olive oil, and tomatoes. In the three experiments an average of 106 grams of fat was eaten daily, with an average digestibility of 89 per cent (91.2 per cent, 84.3 per cent, 91.5 per cent) for the total fat, of which 92 per cent was Brazil-nut oil.

The following experiments were made to determine the digestibility of Brazil-nut oil under conditions similar to those in the other experiments in the present series.

Data of digestion experiments with Brazil-nut oil in a simple mixed diet.

Experiment, subject, and diet.	Weight of foods.	Constituents of foods.				
		Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 551, subject H. R. G.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Blancmange containing Brazil-nut oil	1,399.0	657.4	26.1	168.9	534.4	12.2
Wheat biscuit	259.0	23.3	27.5	3.9	200.2	4.1
Fruit	874.0	759.5	7.0	1.7	101.4	4.4
Sugar	56.0	.....	.....	.....	56.0	.....
Total food consumed	2,588.0	1,440.2	60.6	174.5	892.0	20.7
Feces	74.0	.....	24.3	7.4	36.4	5.9
Amount utilized	.....	.....	36.3	167.1	855.6	14.8
Per cent utilized	.....	.....	59.9	95.8	95.9	71.5
Experiment No. 553, subject P. K.:						
Blancmange containing Brazil-nut oil	2,185.0	1,026.7	40.9	263.7	834.7	19.0
Wheat biscuit	452.0	40.7	47.9	6.8	349.4	7.2
Fruit	866.0	752.6	6.9	1.7	100.5	4.3
Sugar	37.0	.....	.....	.....	37.0	.....
Total food consumed	3,540.0	1,820.0	95.7	272.2	1,321.6	30.5
Feces	85.0	.....	26.1	12.9	38.8	7.2
Amount utilized	.....	.....	69.6	259.3	1,282.8	23.3
Per cent utilized	.....	.....	72.7	95.3	97.0	76.4

[1] Chemical Technology and Analysis of Oils, Fats, and Waxes. London: Macmillan & Co. (Ltd.), 1909, 4 ed., vol. 2, p. 188.
[2] Loc. cit.

Data of digestion experiments with Brazil-nut oil in a simple mixed diet—Contd.

Experiment, subject, and diet.	Weight of foods.	Constituents of foods.				
		Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 554, subject C. J. W.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Blancmange containing Brazil-nut oil	2,477.0	1,163.9	46.3	299.0	946.2	21.6
Wheat biscuit	332.0	29.9	35.2	5.0	256.6	5.3
Fruit	1,045.0	908.1	8.4	2.1	121.2	5.2
Sugar	.....	.....	.....	.....	.....	.....
Total food consumed	3,854.0	2,101.9	89.9	306.1	1,324.0	32.1
Feces	128.0	.....	38.8	23.6	51.1	14.5
Amount utilized	.....	.....	51.1	282.5	1,272.9	17.6
Per cent utilized	.....	.....	56.8	92.3	96.1	54.8
Average food consumed per subject per day	1,109.1	595.8	27.4	83.6	393.1	9.2

Summary of digestion experiments with Brazil-nut oil in a simple mixed diet.

Experiment No.	Subject.	Protein.	Fat.	Carbohydrates.	Ash.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
551	H. R. G	59.9	95.8	95.9	71.5
553	P. K	72.7	95.3	97.0	76.4
554	C. J. W	56.8	92.3	96.1	54.8
	Average	63.1	94.5	96.3	67.6

As indicated by the above experiments the digestibility of the protein, fat, and carbohydrate portions of the diet was 63.1 per cent, 94.5 per cent, and 96.3 per cent, respectively. The value for the digestibility of the total fat of the diet, 94.5 per cent, is increased to 96.3 per cent for Brazil-nut oil alone when account is taken of the metabolic products and any undigested portion of the fat supplied by the basal ration.

The high digestibility of Brazil-nut oil and the relatively high digestibility of Brazil nuts as a whole, as reported by Jaffa,[1] would indicate that from a dietetic standpoint these nuts are worthy the high place accorded them as food.

BUTTERNUT OIL.

The kernel of the butternut (*Juglans cinerea*) when subjected to pressure yields a light yellow oil which apparently has received little attention from investigators. No report was found in the literature of any study of its physical and chemical properties, its use for industrial or edible purposes, or its nutritive value. In view of the high fat content of butternuts—it is reported [2] that the kernels contain over 61 per cent of oil—and of the rather extensive use of butter-

[1] U. S. Dept. Agr., Office Expt. Stas. Bul. 132 (1903).

[2] U. S. Dept. Agr., Office Expt. Stas. Bul. 28 (1899), p. 74, rev. ed.

nuts in some localities, it appeared desirable to determine the digestibility of butternut oil for comparison with the values obtained for the digestibility of other nut oils.

Since it was impossible to procure any butternut oil in the market, 2 bushels of nuts were secured in northern New England. When these had been thoroughly dried the kernels were removed and the oil expressed (cold pressed) with a hydraulic press. The freshly made oil possessed the qualities of a good salad oil and did not exhibit in any appreciable degree the characteristic butternut flavor. The chemical and physical properties of this oil were studied by R. H. Kerr, of the Bureau of Animal Industry, whose report describes it as: A clear, golden yellow oil of mild, pleasant odor, and agreeable taste. The refractive index at 40° was found to be 1.4710, and the iodin number 156.90.

In this study of its digestibility, the butternut oil was, as usual, incorporated in a cornstarch blancmange and served in conjunction with the customary basal ration. Three subjects assisted in this study and the results which were obtained are reported in the table which follows:

Data of digestion experiments with butternut oil in a simple mixed diet.

Experiment, subject, and diet	Weight of foods.	Constituents of foods.				
		Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 732, subject R. F. C.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Blancmange containing butternut oil	1,205.0	589.3	27.5	109.3	473.1	5.8
Wheat biscuit	400.0	36.0	42.4	6.0	309.2	6.4
Fruit	1,381.0	1,200.1	11.0	2.8	160.2	6.9
Sugar	184.0	.....	.....	.....	184.0	.....
Total food consumed	3,170.0	1,825.4	80.9	118.1	1,126.5	19.1
Feces	118.0	.....	44.1	17.4	42.9	13.6
Amount utilized	.....	.....	36.8	100.7	1,083.6	5.5
Per cent utilized	.....	.....	45.5	85.3	96.2	28.8
Experiment No. 733, subject P. K.:						
Blancmange containing butternut oil	1,460.0	714.1	33.3	132.4	573.2	7.0
Wheat biscuit	307.0	27.6	32.6	4.6	237.3	4.9
Fruit	691.0	600.5	5.5	1.4	80.2	3.4
Sugar	257.0	.....	.....	.....	257.0	.....
Total food consumed	2,715.0	1,342.2	71.4	138.4	1,147.7	15.3
Feces	84.0	.....	27.7	19.1	28.9	8.3
Amount utilized	.....	.....	43.7	119.3	1,118.8	7.0
Per cent utilized	.....	.....	61.2	86.2	97.5	45.8
Experiment No. 734, subject J. C. M.:						
Blancmange containing butternut oil	1,612.0	788.4	36.8	146.2	632.9	7.7
Wheat biscuit	387.0	34.8	41.0	5.8	299.2	6.2
Fruit	1,293.0	1,123.6	10.3	2.6	150.0	6.5
Sugar	161.0	.....	.....	.....	161.0	.....
Total food consumed	3,453.0	1,946.8	88.1	154.6	1,243.1	20.4
Feces	75.0	.....	24.1	8.2	35.3	7.4
Amount utilized	.....	.....	64.0	146.4	1,207.8	13.0
Per cent utilized	.....	.....	72.6	94.7	97.2	63.7
Average food consumed per subject per day	1,037.6	568.3	26.7	45.7	390.8	6.1

Summary of digestion experiments with butternut oil in a simple mixed diet.

Experiment No.	Subject.	Protein.	Fat.	Carbohydrates.	Ash.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
732	R. F. C.	45.5	85.3	96.2	28.8
733	P. K.	61.2	86.2	97.5	45.8
734	J. C. M.	72.6	94.7	97.2	63.7
	Average	59.8	88.7	97.0	46.1

The supply of butternut oil obtainable was small and so it was not possible to provide as large a quantity of it per day as was the case with the other oils studied, and the average daily consumption was only 46 grams per man. The butternut-oil blancmange was as palatable as the similar dish used in the other tests, and there is every reason to believe that more of the oil would have been eaten had it been possible to supply a blancmange richer in it. The digestibility of the total fat in the diet was found to be 88.7 per cent. The calculated digestibility of butternut oil alone, which represented the greater part of the total fat, when estimated in the usual manner, with corrections for metabolic products and undigested fat from the basal ration, is 95.4 per cent, a value which compares favorably with the digestibility of other food oils which have been studied.

The protein and carbohydrates supplied by the ration were utilized as completely as in other experiments of this series, being 60 per cent and 97 per cent digested, respectively. Considering the results as a whole, it is apparent that butternut oil, expressed from fresh, sound butternuts, when eaten as a constituent of a simple mixed diet, is a well assimilated and palatable food oil.

ENGLISH-WALNUT OIL.

The English or Persian walnut tree (*Juglans regia*) is widely distributed, and the nuts are very generally used for human food. English-walnut oil is expressed for illuminating and for edible purposes in several parts of Europe. The cold-pressed oil is almost colorless and has a pleasant smell and agreeable taste, while, according to Lewkowitsch,[1] if hot pressed it has a greenish tinge and acrid taste and odor.

A survey of the literature revealed little information as regards the digestibility of English-walnut oil. Jaffa[1] made a series of 11 digestion experiments in which he studied the digestibilty of walnuts eaten in conjunction with other common food materials. On an average the subjects ate 97 grams of fat per day, of which 86 grams was walnut oil. The digestibility of the total fat of the diet was 85 per cent. Since the fat derived from the other constituents of the

[1] Loc. cit.

diet (grapes, granose, pears, milk, apples, dried figs, bananas, oranges, dried prunes, dates) is believed to be very well utilized by the human body, the results of these experiments would indicate that the coefficient of digestibility of walnut oil eaten as a constituent of the nuts would not be far from 85 per cent.

In the experiments here reported the walnut oil, which was cold pressed from a good grade of nuts, was fed in the usual manner to three healthy young men, and the data obtained are recorded in the following table:

Data of digestion experiments with English-walnut oil in a simple mixed diet.

Experiment, subject, and diet.	Weight of foods.	Constituents of foods.				
		Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 355, subject D. G. G.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Blancmange containing walnut oil	1,736.0	918.7	32.5	209.7	566.8	8.3
Wheat biscuit	402.0	36.2	42.6	6.0	310.8	6.4
Fruit	705.0	612.7	5.6	1.4	81.8	3.5
Sugar	107.0	.....	.....	.....	107.0	.....
Total food consumed	2,950.0	1,567.6	80.7	217.1	1,066.4	18.2
Feces	86.0	.....	29.1	9.5	39.4	8.0
Amount utilized	.....	.....	51.6	207.6	1,027.0	10.2
Per cent utilized	.....	.....	63.9	95.6	96.3	56.0
Experiment No. 356, subject R. L. S.:						
Blancmange containing walnut oil	2,081.0	1,101.3	38.9	251.4	679.4	10.0
Wheat biscuit	339.0	30.5	35.9	5.1	262.1	5.4
Fruit	450.0	391.0	3.6	0.9	52.2	2.3
Sugar	96.0	.....	.....	.....	96.0	.....
Total food consumed	2,966.0	1,522.8	78.4	257.4	1,089.7	17.7
Feces	60.0	.....	19.8	12.4	21.8	6.0
Amount utilized	.....	.....	58.6	245.0	1,067.9	11.7
Per cent utilized	.....	.....	74.7	95.2	98.0	66.1
Experiment No. 357, subject O. E. S.:						
Blancmange containing walnut oil	2,026.0	1,072.2	37.9	244.7	661.5	9.7
Wheat biscuit	310.0	27.9	32.9	4.6	239.6	5.0
Fruit	1,341.0	1,165.3	10.7	2.7	155.6	6.7
Sugar	229.0	.....	.....	.....	229.0	.....
Total food consumed	3,906.0	2,265.4	81.5	252.0	1,285.7	21.4
Feces	88.9	.....	24.3	19.0	33.5	11.2
Amount utilized	.....	.....	57.2	233.0	1,252.2	10.2
Per cent utilized	.....	.....	70.2	92.5	97.4	47.7
Average food consumed per subject per day	1,091.3	595.1	26.7	80.7	382.4	6.4

Summary of digestion experiments with English-walnut oil in a simple mixed diet.

Experiment No.	Subject.	Protein.	Fat.	Carbohydrates.	Ash.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
355	D. G. G.	63.9	95.6	96.3	56.0
356	R. L. S.	74.7	95.2	98.0	66.1
357	O. E. S.	70.2	92.5	97.4	47.7
	Average	69.6	94.4	97.2	56.6

The average coefficient of digestibility of the total fat of the diet is 94.4 per cent. If proper allowance is made for the metabolic products and the undigested fat remaining from the basal ration it becomes 97.6 per cent for English-walnut oil alone. The protein and carbohydrate of the diet are shown to be 69.6 per cent and 97.2 per cent digested, respectively.

The difference between the coefficient of digestibility, 97.6 per cent, obtained in these experiments and the 85 per cent or less obtained by Jaffa[1] in his series of 11 digestion experiments, in which the whole nuts were eaten, is thought to be due in part to the form in which the oil was used and may be due in part to Jaffa's considering the ether extract of whole nuts as fat whereas substances other than fat were doubtless extracted, and also may be due in part to no correction being made for metabolic products occurring in the ether extract of the feces. In the latter case it was taken as a constituent of the nut and was probably less readily and completely acted upon by the digestive juices than when it had been mechanically separated and was taken as a separated fat.

The subjects consumed on an average 78 grams (69.9 grams, 83.8 grams, 81.6 grams) of English-walnut oil daily. All three of the subjects reported a laxative effect as a result of the diet; one experienced the effect at the beginning of the test period, one at the end, and one during the entire experimental period. Accordingly, it is believed that the limit of tolerance for this oil is not greatly in excess of 80 grams daily.

HICKORY-NUT OIL.

The oil of the hickory nut (*Carya ovata*) is not separated for edible purposes in this country. It is not without interest to note, however, that the American Indians used hickory-nut oil for food purposes. The oil, according to Carr,[2] was obtained by mixing the pounded nuts in boiling water, straining off the oily liquid, and skimming off the oil which floated on the water in which the nuts were boiled. "[They] kept it in gourds or earthen pots, etc., using it as we do butter on their bread or to give body and flavor to their broth when meat was scarce."[2]

Carr also states that oil was obtained from acorns and used in a similar way.

The digestibility of hickory-nut oil is of interest in view of the large quantities of hickory nuts eaten yearly and especially since the edible portion is reported[3] to contain 67 per cent of oil.

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[1] Loc. cit.

[2] Proc. Amer. Antiquarian Soc., n. ser., 10 (1895), pp. 171, 172, 181. "The Food of Certain American Indians and their Methods of Preparing It."

[3] U. S. Dept. Agr., Office Expt. Stas. Bul. 28 (1906), rev. ed., p. 75.

Since it was impossible to purchase edible hickory-nut oil, a quantity sufficient for the purpose of this investigation was obtained by cold pressing a good grade of nuts purchased in the open market. The resulting oil, which was taken to represent average hickory-nut oil, was of a pale yellow color, without odor, and had a flavor resembling somewhat the nuts from which it was obtained. The supply of oil was very limited, and so no tests were made of its value for table purposes.

The oil, incorporated in the blancmange in the usual manner, was considered only from the standpoint of digestibility, and no attempt was made to determine how much of the oil can be used without producing a laxative effect (limit of tolerance), though it may be assumed that the amount is in excess of that taken in these experiments. The data obtained are given in the following table:

Data of digestion experiments with hickory-nut oil in a simple mixed diet.

Experiment, subject, and diet.	Weight of foods.	Constituents of foods.				
		Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 601, subject A. J. H.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Blancmange containing hickory-nut oil	1,807.0	811.8	38.4	253.0	696.9	6.9
Wheat biscuit	190.0	17.1	20.1	2.9	146.9	3.0
Fruit	.....	.....	.....	.....	.....	.....
Sugar	.....	.....	.....	.....	.....	.....
Total food consumed	1,997.0	828.9	58.5	255.9	843.8	9.9
Feces	21.0	.....	7.6	4.1	6.8	2.5
Amount utilized	.....	.....	50.9	251.8	837.0	7.4
Per cent utilized	.....	.....	87.0	98.4	99.2	74.7
Experiment No. 602, subject P. K.:						
Blancmange containing hickory-nut oil	2,327.0	1,045.5	49.5	325.8	897.4	8.8
Wheat biscuit	402.0	36.2	42.6	6.0	310.8	6.4
Fruit	770.0	669.1	6.2	1.5	89.3	3.9
Sugar	162.0	.....	.....	.....	162.0	.....
Total food consumed	3,661.0	1,750.8	98.3	333.3	1,459.5	19.1
Feces	64.0	.....	20.0	9.8	28.0	6.2
Amount utilized	.....	.....	78.3	323.5	1,431.5	12.9
Per cent utilized	.....	.....	79.7	97.1	98.1	67.5
Experiment No. 603, subject J. C. M.:						
Blancmange containing hickory-nut oil	1,796.0	807.0	38.2	251.4	692.6	6.8
Wheat biscuit	245.0	22.0	26.0	3.7	189.4	3.9
Fruit	682.0	592.7	5.4	1.4	79.1	3.4
Sugar	114.0	.....	.....	.....	114.0	.....
Total food consumed	2,837.0	1,421.7	69.6	256.5	1,075.1	14.1
Feces	81.0	.....	24.9	8.9	38.7	8.5
Amount utilized	.....	.....	44.7	247.6	1,036.4	5.6
Per cent utilized	.....	.....	64.2	96.5	96.4	39.7
Experiment No. 604, subject C. J. W.:						
Blancmange containing hickory-nut oil	2,213.0	994.3	47.0	309.8	853.5	8.4
Wheat biscuit	360.0	32.4	38.2	5.4	278.3	5.7
Fruit	576.0	500.5	4.6	1.2	66.8	2.9
Sugar	81.0	.....	.....	.....	81.0	.....
Total food consumed	3,230.0	1,527.2	89.8	316.4	1,279.6	17.0
Feces	81.0	.....	26.7	10.1	37.1	7.1
Amount utilized	.....	.....	63.1	306.3	1,242.5	9.9
Per cent utilized	.....	.....	70.3	96.8	97.1	58.2
Average food consumed per subject per day	977.1	460.7	26.3	96.9	388.2	5.0

Summary of digestion experiments with hickory-nut oil in a simple mixed diet.

Experiment No.	Subject.	Protein.	Fat.	Carbohydrates.	Ash.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
601	A. J. H.	87.0	98.4	99.2	74.7
602	P. K.	79.7	97.1	98.1	67.5
603	J. C. M.	64.2	96.5	96.4	39.7
604	C. J. W.	70.3	96.8	97.1	58.2
	Average	75.3	97.2	97.7	60.0

The average coefficient of digestibility of the fat eaten, of which over 98 per cent was hickory-nut oil, was 97.2 per cent, while 75.3 per cent of the protein and 97.7 per cent of the carbohydrates were retained in the body. The value for the digestibility of hickory-nut oil alone, obtained by making allowance for the metabolic products and the undigested fat resulting from the accessory foods of the diet, is 99.3 per cent. The subjects consumed an average of 95 grams of hickory-nut oil daily without any physiological disturbances. Thus it may be reasonably concluded that if hickory-nut oil were available in quantity it would prove very satisfactory for food purposes.

PECAN OIL.

This oil is obtained from the nuts of *Carya pecan*, which are native and also largely cultivated in North America. Pecan oil, although it possesses the characteristics of a salad oil, is not expressed for edible purposes on a commercial basis. However, since the wide use of the kernels as food entails a corresponding consumption of the oil, and since the expressed oil appears to be well suited for table purposes, it seemed desirable to include pecan oil among the nut oils to be studied.

No reports of digestion experiments made with pecan oil were found in the literature. Jaffa[1] reports four experiments made to study the relative digestibility of the nuts eaten with fruits. Of a total of 78 grams of fat eaten per man per day, 74 grams was derived from pecans, which were included in a simple diet containing common fruits and nuts. The total fat of the diet was found to be 85 per cent digested, but since over 94 per cent of the entire fat eaten was supplied by the pecans this value should, so far as these results are concerned, approximate the coefficient of digestibility of the oil in pecans. The low value, 85 per cent, may be due partly to the subjects not masticating the nuts to such a degree of fineness that the body could completely assimilate the fat in them.

Four experiments were made in the present series to determine the digestibility of pecan oil when eaten under conditions identical with

[1] Loc. cit.

those maintained for the test periods with other edible fats studied. The results obtained are included in the table which follows.

Data of digestion experiments with pecan oil in a simple mixed diet.

Experiment, subject, and diet.	Weight of foods.	Constituents of foods.				
		Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 405, subject D. G. G.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Blancmange containing pecan oil	1,857.0	864.4	37.2	291.7	655.9	7.8
Wheat biscuit	315.0	28.4	33.4	4.7	243.5	5.0
Fruit	1,341.0	1,165.3	10.7	2.7	155.6	6.7
Sugar	121.0	.....	.....	.....	121.0	.....
Total food consumed	3,634.0	2,058.1	81.3	299.1	1,176.0	19.5
Feces	104.0	.....	34.3	19.0	39.5	11.2
Amount utilized	.....	.....	47.0	280.1	1,136.5	8.3
Per cent utilized	.....	.....	57.8	93.6	96.6	42.6
Experiment No. 406, subject A. J. H.:						
Blancmange containing pecan oil	2,474.0	1,151.6	49.5	388.7	873.8	10.4
Wheat biscuit	575.0	51.8	60.9	8.6	444.5	9.2
Fruit	1,413.0	1,227.9	11.3	2.8	163.9	7.1
Sugar	66.0	.....	.....	.....	66.0	.....
Total food consumed	4,528.0	2,431.3	121.7	400.1	1,548.2	26.7
Feces	127.0	.....	42.3	19.6	51.1	14.0
Amount utilized	.....	.....	79.4	380.5	1,497.1	12.7
Per cent utilized	.....	.....	65.2	95.1	96.7	47.6
Experiment No. 407, subject R. L. S.:						
Blancmange containing pecan oil	1,780.0	828.6	35.6	279.6	628.7	7.5
Wheat biscuit	294.0	26.4	31.2	4.4	227.3	4.7
Fruit	969.0	842.1	7.8	1.9	112.4	4.8
Sugar	117.0	.....	.....	.....	117.0	.....
Total food consumed	3,160.0	1,697.1	74.6	285.9	1,085.4	17.0
Feces	46.0	.....	12.8	8.9	18.4	5.9
Amount utilized	.....	.....	61.8	277.0	1,067.0	11.1
Per cent utilized	.....	.....	82.8	96.9	98.3	65.3
Experiment No. 408, subject O. E. S.:						
Blancmange containing pecan oil	1,834.0	853.7	36.7	288.1	647.8	7.7
Wheat biscuit	246.0	22.1	26.1	3.7	190.2	3.9
Fruit	1,202.0	1,044.6	9.6	2.4	139.4	6.0
Sugar	240.0	.....	.....	.....	240.0	.....
Total food consumed	3,522.0	1,920.4	72.4	294.2	1,217.4	17.6
Feces	107.0	.....	30.8	29.0	36.3	10.9
Amount utilized	.....	.....	41.6	265.2	1,181.1	6.7
Per cent utilized	.....	.....	57.5	90.1	97.0	38.1
Average food consumed per subject per day	1,237.0	675.6	29.2	106.6	418.9	6.7

Summary of digestion experiments with pecan oil in a simple mixed diet.

Experiment No.	Subject.	Protein.	Fat.	Carbohydrates.	Ash.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
405	D. G. G.	57.8	93.6	96.6	42.6
406	A. J. H.	65.2	95.1	96.7	47.6
407	R. L. S.	82.8	96.9	98.3	65.3
408	O. E. S.	57.5	90.1	97.0	38.1
	Average	65.9	93.9	97.2	48.4

The above data indicate that an average of 107 grams of fat, of which 104 grams was pecan oil, was eaten per subject per day for

the four test periods which were made to determine the digestibility of pecan oil. The coefficients of digestibility for the constituents of the diet were for protein, 65.9 per cent; for fat, 93.9 per cent; and for carbohydrates, 97.2 per cent. Experiments made to determine the significance of the ether extract of the feces resulting from the basal ration without the addition of fat have been reported in an earlier paper;[1] making allowance for that portion of the ether extract of the feces which results from the basal ration, the value for the digestibility of the total fat, 93.9 per cent, becomes 96.8 per cent for the pecan oil alone.

CONCLUSIONS.

An average of 70 grams of almond, 56 grams of black-walnut, 81 grams of Brazil-nut, 43 grams of butternut, 78 grams of English-walnut, 95 grams of hickory-nut, and 104 grams of pecan oil was eaten per subject per day in the experiments, out of a total of 71 grams, 68 grams, 84 grams, 46 grams, 80 grams, 97 grams, and 107 grams of fat supplied by the respective diets.

The oils studied in this investigation were found to be well digested, the coefficients of digestibility being 97.1 per cent for almond oil, 97.5 per cent for black-walnut oil, 96.3 per cent for Brazil-nut oil, 95.4 per cent for butternut oil, 97.6 per cent for English-walnut oil, 99.3 per cent for hickory-nut oil, and 96.8 per cent for pecan oil.

The nut oils, which are liquid at ordinary temperatures, have practically the same digestibility as the common vegetable oils (cotton-seed, peanut, olive, sesame, and coconut oils), which are also liquid at ordinary temperatures.

While in these experiments as much as 81 grams of almond oil, 64 grams of black-walnut oil, 100 grams of Brazil-nut oil, 49 grams of butternut oil, 109 grams of hickory-nut oil, and 130 grams of pecan oil were eaten per day by one of the subjects for a 3-day test period, no laxative effect was noted; accordingly the limits of tolerance for these fats is in excess of these amounts. In the experiments with English-walnut oil the three subjects are 69.9 grams, 83.8 grams, and 81.6 grams per day and all reported a slight laxative effect.

The values obtained for the digestibility of the protein and carbohydrates eaten in conjunction with the different nut oils are in agreement with those obtained in the earlier experiments of this series, indicating that the nut oils did not exert any unusual influence on the digestibility of the foods eaten with them.

The results of this study of the digestibility of these nut oils indicate that they are very well assimilated by the human body, and that whenever available they could be used freely for food purposes.

[1] U. S. Dept. Agr. Bul. 310 (1915), p. 17.

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